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AN EVALUATION OF OZONE INJURY TO PINES ON THE TAHOE NATIONAL FOREST

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PSW FOREST AND RANGE EXPERIMENT STATION
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ABSTRACT

Forest Pest Management personnel conducted an ozone injury survey on the Tahoe National Forest in September and October, 1983. Ambient ozone dosages were also monitored at the Foresthill Ranger Station, Tahoe National Forest.

Ozone injury was generally light and scattered throughout the western and southern portions of the Forest. About 57 percent of the plots had trees with symptoms, but only 17 percent of all ponderosa and Jeffrey pines on these plots had oxidant symptoms.

California State Air Pollutiton Standard (10 parts ozone per hundred million) was exceeded 6 times at the Foresthill Ranger Station. The Federal Standard (12 parts per hundred million) was not exceeded.

The ozone injury survey showed that there were about the same number of trees with foliar symptoms on the Tahoe National Forest as on the Eldorado National Forest surveyed in 1982. This is less than occurs in the National Forests to the south.

INTRODUCTION

Ozone injury symptoms have been reported on pines in the Sierra Nevada of central California since 1971 (Miller and Millecan, 1971). The status of ozone injury in the southern Sierra Nevada has been followed by the Forest Pest Management (FPM) Staff since 1976. In 1981, the FPM Staff began to describe and assess the air pollution situation in the central Sierra Nevada using ozone injury ground plots and ozone dose

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monitoring. Ozone injury surveys were conducted on the Stanislaus National Forest in 1981 (Allison, 1982) and on the Eldorado National Forest in 1982 (Allison, 1984). These surveys showed there were fewer trees with foliar symptoms on the Eldorado National Forest than on the Stanislaus, Sierra, and Sequoia National Forests.

In an effort to further describe and delimit the extent of ozone symptoms in the central Sierra Nevada, an ozone injury survey was conducted on the Tahoe National Forest.

OZONE INJURY GROUND SURVEY

In September and October, 1983, the FPM Staff conducted a ground survey of ozone injury to pines on the Tahoe National Forest. Only ponderosa and Jeffrey pines were included because they are the conifers most sensitive to and injured by ozone in California.

Ozone symptoms include a characteristic chlorotic mottle on the needles of affected pines in addition to reduced needle length and reduced needle retention. The ozone symptoms appear first on the oldest needles and lowest branches and, with increasing injury, progress to the younger needles and upper branches. With increasing exposure to ozone, younger whorls of needles are injured and cast, the needle complement of the tree is reduced, the tree enters a period of slow decline, and the tree eventually dies or is killed in its weakened condition. We distinquish between injury and damage in the following way: injury includes any abnormal changes in the appearance or function of a tree (such as chlorosis and needle cast), whereas damage involves a measurable decrease in growth or economic value of a tree. We did not collect growth data during the survey and, therefore, our comments are restricted to levels of visible oxidant injury and not to measured amounts of tree damage.

Methods

Potential plot sites were systematically selected, so there would be one plot per township within the Tahoe National Forest. Plot selection was made in consultation with both the Forest and District silviculturists because they would know if the plots would meet our plot selection criteria in terms of size and numbers of trees and accessibility. Plot sites were considered valid if ten ponderosa and/or Jeffrey pines were found within an area one chain (20 meters) by six chains (121 meters) on each side of and parallel to the road. The near edge of each plot was separated from the roadside by at least one-half chain (10 meters). Within each plot, various site and tree characteristics were observed. Some of the important site data collected included plot elevation, location, aspect, topography, and slope; and stand type, size class, and density. Tree data collected included species, dbh, crown position, live-crown ratio, other pests present, and ozone injury rating. Pest data were collected to avoid confusing other abiotic or biotic symptoms with ozone injury.

Ozone symptoms were evaluated and rated by examining branches from the lower crown of each tree. The scoring system used is described in Table 1. It is based on the severity of chlorotic mottle present on pine foliage. Pines with symptoms were given a score between 0 and 4, the number indicating how many years of retained needles were healthy or free of chlorotic mottle. Trees with no symptoms and trees with symptoms on only fifth-year or older needles received scores of 4. The 10 individual tree scores from each plot were averaged to yield a plot score, and the overall injury level for each plot was described as listed under "Extent of Injury" in Table 1.

Table 1. FPM OZONE INJURY SCORING SYSTEM FOR PINES.

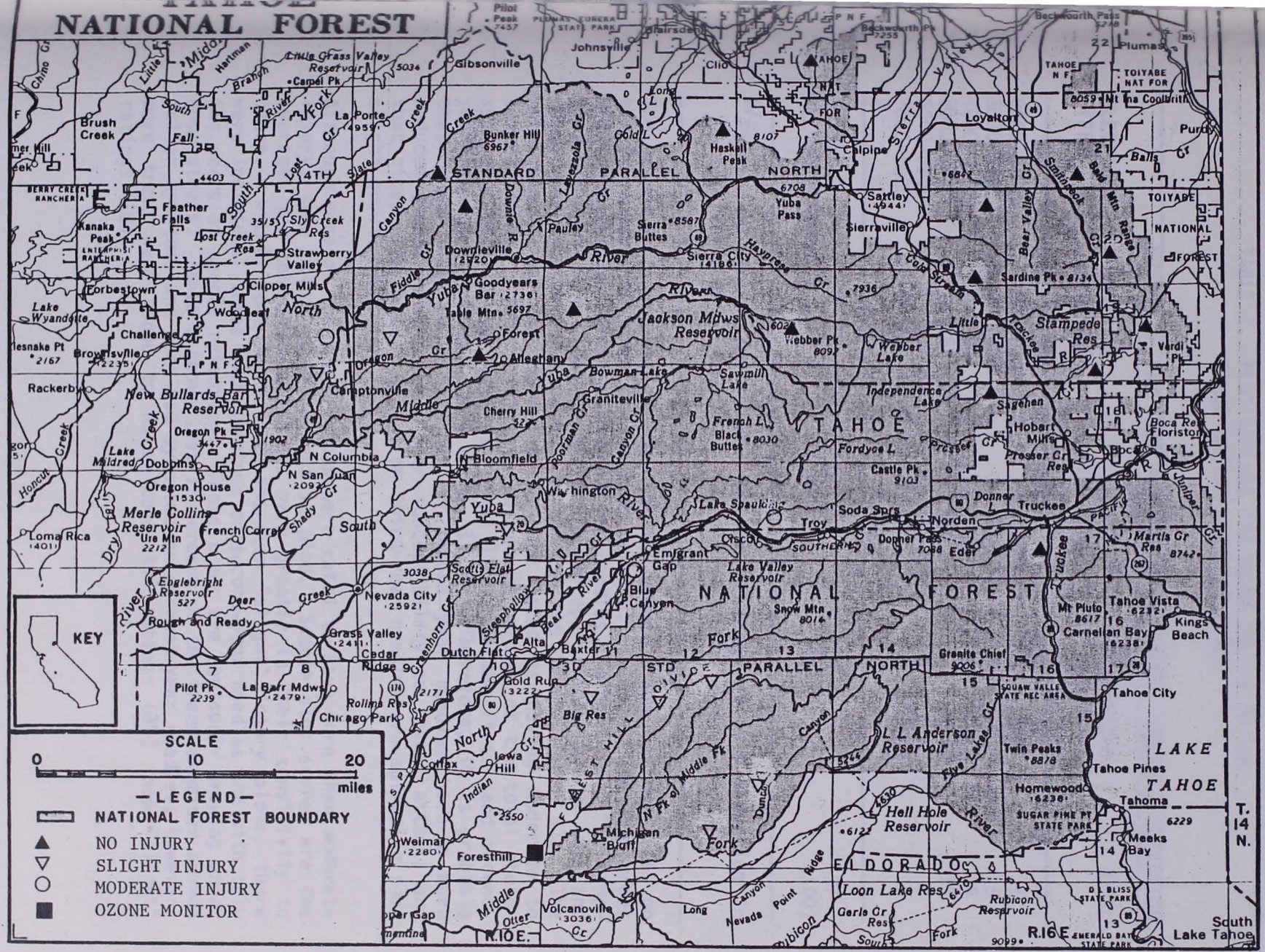
INDIVIDUAL TREE SCORE	YOUNGEST NEEDLES WITH SYMPTOMS	AVERAGE PLOT SCORE	EXTENT OF INJURY
0	Current Year	0 - 0.9	Very Severe
1	Second Year	1.0 - 1.9	Severe
2	Third Year	2.0 - 2.9	Moderate
3	Fourth Year	3.0 - 3.9	Slight
4	Fifth & Older or No Symptoms	4.0	None

Plot Locations

The location of the plots and the ozone injury ratings were placed on a map of the survey area. Figure 1 was drawn from this map.

RESULTS

Ozone injury was generally slight and scattered throughout the Forest. About 57 percent of the 37 plots exhibited slight to moderate symptoms of oxidant injury (Table 2). No plots had injury ratings above moderate. Plots with moderate injury were found at elevations from 3000 to 6900 feet. Plots at elevations over 7000 feet were free of oxidant injury symptoms. The level of injury decreased at higher elevations and in areas further removed from the Central Valley and major air drainages.


NATIONAL FOREST
KEY
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EL DORADO
LAKE TAHOE
Jackson Mdws Reservoir
Stampede Res
New Bullards Bar Reservoir
Merle Collins Reservoir
Englebright Reservoir
South Feather Reservoir
L L Anderson Reservoir
Hell Hole Reservoir
Rubicon Reservoir
Lake Valley Reservoir
Lake Spaulding
Independence Lake
Webber Lake
Sawmill Lake
Bowman Lake
Loon Lake Res
Gerle Cr Res
Martis Cr Res
Boca Res
Prosser Cr Res
Rollins Res
Big Res
Sugar Pine Pt State Park
D L Bliss State Park
Emerald Bay State Park
Squaw Valley State Rec Area
Tahoe City
Tahoe Pines
Homewood
Tahoma
Meeks Bay
South Lake Tahoe
Truckee
Donner Pass
Soda Spgs
Norden
Cisco
Emigrant Gap
Blue Canyon
Nevada City
Grass Valley
Dutch Flat
Alta
Baxter
Colfax
Foresthill
Weimar
Michigan Bluff
Cedar Ridge
Rough and Ready
Oregon House
Dobbins
Challenge
Forbestown
Brownsville
Oroville
Downieville
Sierra City
Sierraville
Loyalton
Gibsonville
Johnsville
Plumas
Quincy
Graeagle
Portola
Truckee
Tahoe City
Kings Beach
Carnelian Bay
Tahoe Vista
Incline Village
Crystal Bay
Reno
Verdi
Floriston
Hobart Mills
Sagehen
Fordyce L
French L
Castle Pk 9103
Mt Pluto 8617
Granite Chief 9006
Snow Mtn 8014
Twin Peaks 8878
Haskell Peak 8107
Sierra Buttes 8587
Webber Pk 8097
Sardine Pk 8134
Mt Ina Coolbrith 8059
Bunker Hill 6967
Yuba Pass 6708
Table Mtn 5697
Oregon Pk 3447
Pilot Pk 2239
Pilot Peak 7457
Beckwourth Pass 5240
Beckwourth Pk 7253
Little Grass Valley Reservoir 5034
Camel Pk
La Porte 4959
Feather Falls
Kanaka Peak
Lost Creek Res
Sly Creek Res
Strawberry Valley
Clipper Mills
Goodyears Bar 2736
Woodleaf
Lake Wyandotte
Rackerby
Oregon Creek
Cherry Hill
Graniteville
Camptonville
Lake Mildred
N Columbia
N Bloomfield
N San Juan 2093
Loma Rica 1401
Dry Creek
Honcut Creek
Yuba River
Middle Yuba River
North Yuba River
South Yuba River
Fiddle Cr
Canyon Cr
Downie R
Lavezola Cr
Poorman Cr
Washington
Shady Creek
Deer Creek
Greenhorn Cr
Steephollow Cr
Bear River
Dry Creek
Little Truckee River
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Sierra Valley
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Smithneck Cr
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Little Truckee
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Little South Fork
Middle Fork
North Fork
Five Lakes Cr
Dumbell
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Canyon
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Otter Cr
Long Canyon
Nevada Point
Rubicon
South Fork
Indian
Iowa Hill
Volcanoville 3036
Chicago Park
La Barr Mdws 2479
Pilot Pk 2239
Eagleblight Reservoir 527
Deer Creek
Shady Creek
Dry Creek
Honcut Creek
Yuba River
Middle Yuba River
North Yuba River
South Yuba River
Fiddle Cr
Canyon Cr
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Lavezola Cr
Poorman Cr
Washington
Shady Creek
Deer Creek
Greenhorn Cr
Steephollow Cr
Bear River
Dry Creek
Little Truckee River
Truckee River
Sierra Valley
Bear Valley
Smithneck Cr
Balls Cr

TABLE 2. PLOT RATINGS FOR OZONE INJURY ON THE TAHOE NATIONAL FOREST, 1983

ELEVATION (FEET)	NUMBER OF SAMPLING PLOTS BY OZONE INJURY RATING & ELEVATION						TOTAL
	MODERATE (2.0-2.9)		SLIGHT (3.0-3.9)		NO SYMPTOMS (4.0)		
2000-2900	0	(0)[1]	1	(100)	0	(0)	1
3000-3900	2	(40)	3	(60)	0	(0)	5
4000-4900	0	(0)	7	(78)	2	(22)	9
5000-5900	1	(8)	5	(38)	7	(54)	13
6000-6900	1	(14.3)	1	(14.3)	5	(71.4)	7
7000-7900	0	(0)	0	(0)	2	(100)	2
TOTAL ALL ELEVATIONS	4	(11)	17	(46)	16	(43)	37 (100)

[1/] Figure in parentheses is the percent of trees of this elevation in this injury class.

The amount of damage being done to the ponderosa and Jeffrey pines on the Tahoe National Forest by ozone is unknown. In our estimation, trees with symptoms on fourth-year or older needles ("slight" and "no symptoms" ratings) are probably not suffering appreciable growth loss and these two categories account for 88% of the trees (Table 3). The remaining 12 percent of the trees were rated as having moderate to severe injury. Normally between 60 and 80 percent of the total photosynthetic activity of ponderosa pines lies with the first- and second-year needles (Freeland, 1952, Helms, 1970). Therefore, it is probable that trees with oxidant injury on second year needles have a much reduced growth rate and a higher susceptibility to insect attack; and that pines with oxidant injury on third-year needles are suffering some slight growth reduction.

Although none of the survey plots were rated to have more than moderate injury, some points must be kept in mind. Sample plot scores are the averages for ten trees and pines vary greatly in their sensitivity to ozone. Within some "moderate" and even "slight" injury plots, there were individual trees with symptoms on second-year needles and with only two years of needle retention. These trees are obviously growing under some stress. Table 3 shows that 17 percent of the trees examined showed foliar symptoms and none had symptoms on current-year needles; however, more trees were found to have "moderate" ratings (30) than "slight" ratings (18).

TABLE 3. THE NUMBER AND PERCENTAGE OF INDIVIDUAL PONDEROSA AND JEFFREY PINES BY OZONE INJURY RATING, TAHOE NATIONAL FOREST, 1983.

(TOTAL TREES - 370)

TREE RATING		NUMBER OF TREES	PERCENT TREES
NO SYMPTOMS	(4)[1/]	307	83
SLIGHT	(3)	18	5
MODERATE	(2)	30	8
SEVERE	(1)	15	4
TOTAL		370	100

[1/] Injury rating score

ASSOCIATED INSECT AND DISEASE PESTS

The insects most commonly observed on the surveyed pines were pine needle scale (Chinospis pinifoliae) and aphids (Cinara spp.). Western gall rust (Peridermium harknessii), and dwarf mistletoe (Arceuthobium campylopodum) were the most commonly encountered tree diseases.

DISCUSSION

Table 4 compares oxidant injury ratings on plots and individual trees among the three Forests in the central Sierra Nevada (Eldorado, Stanislaus, and Tahoe National Forests). The 57 percent of plots exhibiting symptoms of oxidant injury on the Tahoe is slightly higher than the 50 percent of plots exhibiting oxidant symptoms on the Eldorado, but is much lower than the 83 percent of plots exhibiting oxidant symptoms on the Stanislaus, or the 79 percent combined results of injury trend plots evaluated on the Sierra and Sequoia National Forests in 1979/80 (Pronos and Vogler, 1981). Plots with moderate injury were found at elevations up to 7000 feet on the Tahoe National Forest. This differs from the Eldorado where all plots with moderate injury were found at elevations less than 4000 feet, and from the Stanislaus, where all plots with moderate injury were found at elevations less than 5000 feet. In the southern Sierra Nevada, plots with moderate injury were found at all elevations except 8000 feet. These elevational differences in symptom expression are most likely due to basic differences in mass air and ozone movement up the slopes of these National Forests. Tables 3 and 5 show that about 83 percent of the

individual trees on the Tahoe had no oxidant symptoms. This is essentially the same as the Eldorado which had no oxidant symptoms on 86 percent of the trees, but differs from the Stanislaus where only 70 percent of the trees had no oxidant symptoms.

TABLE 4. OZONE INJURY RATINGS OF PLOTS AND INDIVIDUAL PONDEROSA AND JEFFREY PINES ON THE TAHOE, ELDORADO, AND STANISLAUS NATIONAL FORESTS.

NATIONAL FOREST	PLOTS					INDIVIDUAL TREES				
	A[1]	B	C	D	E	A[1]	B	C	D	E
TAHOE 1983	0	0	4	17	16	0	15	30	18	307
ELDORADO 1982	0	0	3	12	15	0	16	14	11	259
STANISLAUS 1981	0	0	7	31	8	2	29	73	32	324

[1] A = Very Severe
B = Severe
C = Moderate
D = Slight
E = No Injury

TABLE 5. THE PERCENTAGE OF INDIVIDUAL PONDEROSA AND JEFFREY PINES BY OZONE RATING ON THE TAHOE, ELDORADO, AND THE STANISLAUS NATIONAL FORESTS.

NATIONAL FOREST	INDIVIDUAL TREES				
	VERY SEVERE	SEVERE	MODERATE	SLIGHT	NONE
Tahoe, 1983	0	4	8	5	83
Eldorado, 1982	0	5	5	4	86
Stanislaus, 1981	0.4	6.4	15.9	6.9	70.4

CONCLUSIONS

Ozone symptoms are found on pine throughout much of the southern and central Sierra Nevada. The Tahoe, Eldorado and Stanislaus surveys indicate that ozone symptoms occur less frequently and are not as severe on the northern National Forests.

Our recent ozone surveys have shown that ozone symptoms are not often found at the higher elevations away from the Central Valley and major air drainages through the mountains. Although ozone injury symptoms are readily found on the Tahoe National Forest, ozone is not presently causing significant damage to pines on a Forest-wide basis.

OZONE MONITORING

The Forest Pest Management (FPM) Staff began measuring ozone levels in the central Sierra Nevada in 1982. In 1983, the FPM Staff conducted season-long (June-October) monitoring at the Foresthill Ranger Station, Tahoe National Forest (3000 feet). The ozone monitor site is shown in Figure 1.

TABLE 6. OZONE CONCENTRATION AT FORESTHILL RANGER STATION, TAHOE NATIONAL FOREST, JUNE-OCTOBER, 1983. (CONCENTRATIONS ARE EXPRESSED AS MAXIMUM HOURLY AVERAGES AND MEANS OF DAILY MAXIMUM HOURLY AVERAGES, AND ARE SHOWN AS PARTS PER HUNDRED MILLION (Pphm).

MONTH	MAXIMUM HOURLY AVERAGE (Pphm)	MEAN OF MAXIMUM HOURS (Pphm)
JUNE	7	6.0
JULY	11	7.3
AUGUST	12	7.4
SEPTEMBER	8	6.0
OCTOBER	10	5.8
NOVEMBER	4	3.0

TABLE 7. COMPARISON OF OZONE CONCENTRATION AT THREE SITES IN THE CENTRAL SIERRA NEVADA (GEORGETOWN RANGER STATION, ARNOLD CDF STATION, AND FORESTHILL RANGER STATION, MAY-OCTOBER 1982-83. (CONCENTRATIONS ARE EXPRESSED AS MAXIMUM HOURLY AVERAGES, AND ARE SHOWN AS PARTS PER HUNDRED MILLION (Pphm).

	GEORGETOWN (82)		ARNOLD (82)		FORESTHILL (83)	
MONTH	MHA[1]	MMH[2]	MHA[1]	MMH[2]	MHA[1]	MMH[2]
MAY	7	6.0	7	6.3	-	-
JUNE	10	7.0	11	6.5	7	6.0
JULY	14	8.5	9	7.0	11	7.3
AUGUST	13	8.5	10	7.0	12	7.4
SEPTEMBER	9	5.0	15	6.0	8	6.0
OCTOBER	8	4.0	7	5.5	10	5.8

1/MHA = Maximum Hourly Average (Pphm)

2/MMH = Mean of Maximum Hours (Pphm)

TABLE 8. NUMBER OF HOURS DURING WHICH THE CALIFORNIA STATE OZONE STANDARD (10 Pphm) WAS EQUALLED OR EXCEEDED AT FORESTHILL RANGER STATION, TAHOE NATIONAL FOREST DURING JUNE THROUGH OCTOBER, 1983.

YEAR	% OF HOURS MONITORED	NUMBER OF HOURS DURING WHICH STATE STANDARD WAS EXCEEDED					
		JUNE	JULY	AUG.	SEPT.	OCT.	TOTAL
Foresthill 1983	68	0	4	2	0	0	6

METHODS

Ozone concentrations were measured with Dasibi ozone monitors calibrated by the State of California Air Resources Board and maintained by the FPM Staff. Ambient air samples were collected through Teflon tubing with sample inlets located 20 to 26 feet (6 to 8 meters) above the ground level. Span frequencies were set to compensate for elevation according to Air Resource Board specifications.

RESULTS AND DISCUSSION

Ambient ozone concentrations occurring at the Foresthill Ranger Station, Tahoe National Forest, are shown in Table 6. Similar ozone data from Georgetown Ranger Station, Eldorado National Forest and California Department of Forestry Fire Station at Arnold are compared with ozone data from Foresthill Ranger Station in Table 7. Results from Table 6 show that ozone concentrations reached their highest levels in July and August. Table 7 shows that ozone levels in the northern portion of the central Sierra Nevada do not differ greatly from those further south in the central Sierra Nevada, but they continue to be much lower than the levels recorded in the southern Sierra Nevada (Vogler, 1982). The maximum hourly averages and means of the daily maxima at Foresthill closely parallel those at Georgetown and Arnold (Table 6 and 7).

The California State Standard (10 parts per hundred million) was exceeded 6 times at Foresthill Ranger Station (Table 8). These results were approximately the same as those at Arnold, but differed greatly from those at Georgetown, where the State standard was exceeded 21 times from June to August (Allison, 1984). The State Standard was exceeded in both July and August (Table 8). The State Standard was exceeded in June, July, and August at Georgetown and in June and September at Arnold. The Federal Standard for ozone (12 parts per hundred million) was not exceeded at Foresthill.

CONCLUSIONS

We conclude that (1) ozone symptoms are common but not as widespread or as intense in the central Sierra Nevada as they are in much of the southern Sierra; (2) ozone is causing only slight needle injury on a Forest-wide basis; (3) a few locations with moderately - injured pines do exist; (4) the worst injury found was located along major river drainages major highways, close to the central valley, or under 7000 feet; and (5) ozone injury is not severe enough to be causing much damage or loss in the Tahoe National Forest.

Our monitoring in the central Sierra Nevada has shown a decrease in ozone concentrations as you move from the southern Sierra north to the Tahoe National Forest. The northern extent of ozone symptoms will not be known until ozone surveys are conducted on Forests to the north of the Tahoe.

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